Comparing surface activity and flight of predatory arthropods in a 5 km transect

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Abstract

To analyze the dispersal activity of the whole complex of predatory arthropods in an agricultural area, we applied the trap transect method over a distance of 5 km in an intensely farmed landscape. Twenty trap stations were set up between an isolated piece of wetland and an isolated dry meadow bordered by mixed forest. The trap stations consisted of identical sets of window (interception) traps, sticky grid traps and yellow water pan traps for catching flying arthropods, and two types of pitfall traps, sweep net samples and suction samples for measuring surface activity.

319 species with five or more specimens collected (with a total of over 122,000 individuals) are displayed in a two-dimensional transect distribution. For all species with more than ten individuals a three-dimensional plot is used to show seasonal changes in the distribution.

Species are grouped and sorted according to various indices such as the number of specimens, the percentage of flight activity, an index of "naturalness", and one of five distribution types defined from the two-dimensional transect. Based on the information of these indices, each species is assigned to one of six dispersal types. Grouping for dispersal behavior allows a quantitative interpretation of the habitat requirements in view of either biodiversity (number of species) or biological control (number of individuals).

The large number of standardized collecting methods and the large number of taxa considered will make this data set a useful empirical base for modelling spatial and temporal aspects of dispersal and metapopulation dynamics.

Key words: Predators, arthropods, transect, dispersal, agroecosystems

Introduction

Trap transects have so far mainly been used for monitoring within-field or between-field movements of arthropods. Our knowledge of dispersal activities over larger distances, on a regional scale, is restricted to some selected insect

Arthropod natural enemies in arable land "I *Density, spatial heterogeneity and dispersal*
S. Toft & W. Riedel (eds.). *Acta Jutlandica* vol. 70:2 1995, pp. 283-293.
 ISBN 87 7288 492

species of agricultural importance. But to what extent is it possible to extrapolate the results from single species to the relevant taxonomic group or even the ecological guild of species?

To look at as many species as possible within the whole complex of predatory arthropods in an agricultural landscape, we applied the trap transect method over a distance of 5 km in an intensely farmed landscape. By comparing the distribution patterns in space and time of both surface activities and flight, we can assign specific dispersal types to the more abundant species. The type of the distribution pattern and, accordingly, the presumed dispersal activity allows an assessment of the regional habitat requirements for the various types of predatory species in agricultural areas. The main purpose of this analysis is to quantify the contribution of the different dispersal and hibernation types in order to set priorities for landscape planning in agricultural extensification programs.

Materials and methods

The transect in the Limpach valley northwest of Bern, Switzerland, consisted of twenty trap stations. It started with two trap stations in an isolated piece of wetland (the nearest other wetland being at a distance of 7 km) and ended with one trap station in another isolated habitat, a dry meadow (Mesobrometum) along the edge of a mixed forest. Between these two regionally unique natural or seminatural habitats, there was a flat plain with a mosaic of small (maximum 1.5 ha) cultivated fields and fertilized grassland. The trap stations in the cultivated land were located at distances of 200 - 300 m in the center of either wheat or maize fields, or in fertilized grassland. To obtain data from an equally long period of trapping in all habitat types, the traps in the wheat fields were all removed after wheat harvest in July and reinstalled in the nearest maize fields. Each trap station consisted of a set of one window (interception) trap (Fürst & Duelli 1988, Stöckli & Duelli 1989), one sticky grid trap (Huber & Duelli 1987), one yellow water pan trap and three pitfall traps. Two of the pitfall traps were funnel traps with a diameter of 15 cm, one was a standard plastic cup of 7 cm diameter. Sweep net samples every two weeks consisted of 100 sweeps per trap station.

The traps were operated for one full year in 1987 and emptied at weekly intervals. The most important groups of predatory arthropods were identified to the species level. The weather conditions in 1987 were somewhat unusual, with snow and ice until the end of March, a rainy spring, and an extremely warm autumn with temperatures up to 18°C around Christmas.

All species with five or more individuals collected were displayed in a two-

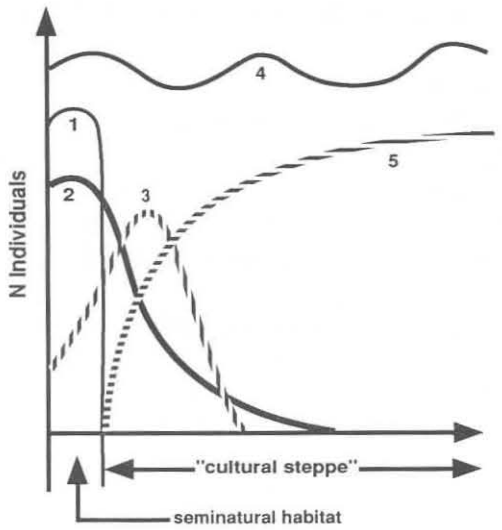

Fig. 1. The five categories to characterise transect distribution types. 1 - captures only in seminatural habitats; 2 - maximum captures in seminatural habitats, with gradual decrease into agricultural areas; 3 - maximum captures very close to seminatural habitats; 4 - species distributed in all habitats; 5 - captures almost exclusively in cultivated areas.

dimensional transect distribution graph (Duelli et al. 1992). Species with more than ten specimens were displayed in a three-dimensional graph, with axes for number of individuals, space and time.

Results

The role of natural habitats as "ecological compensation areas"

The primary goal of this transect study in 1987 was to quantify the contribution of natural or seminatural areas to the overall biodiversity of an agricultural landscape. So we first focussed on species with a distribution pattern in the transect which indicated that the natural areas are a vital source or an important hibernation habitat for those species. For this purpose each species, including all the non-predatory species, was assigned to one of five distribution types (Fig. 1). Species of the types 1 - 3 (stenotopic in natural areas, diffusion from a maximum in the natural areas into the cultivated fields, maximum in cultivated areas bordering the natural areas) were considered to depend, at least at one point in time during their lives, on the presence of natural areas. An average of 60% of

all species in seven arthropod groups belonged to the distribution types 1, 2 or 3 (Duelli et al. 1992).

We can assume that a lot of the species considered to be "ubiquists" or "cultural species" (types 4 and 5) also depend on natural habitats such as hedgerows or forest edges for overwintering. Thus the contribution of natural or seminatural areas to the overall biodiversity of an agricultural landscape was certainly underestimated with our average of 60%, based solely on the two-dimensional transect distribution, which does not show seasonal differences.

Estimating the potential for genetic exchange between isolated natural habitats

A second goal of the transect distribution graphs was to develop a dispersal model for species with a stronghold in natural habitats, and a measurable diffusion into the cultivated areas (type 2 in Fig.1). Distribution patterns for all type 2 species were fitted to various published dispersal functions (Taylor 1978). The equation with the best fit was used to calculate the distances from a natural habitat, where 1%, 0.1% or 0.01% of the total number of individuals captured in the trap station in the natural area were expected to be collected (Duelli et al. 1992). In a model we can thus estimate the probability for a given population to reach another potentially suitable habitat. Furthermore, we can roughly estimate how many of the species from a taxonomic group will be able to reach a habitat in a given distance with at least one propagule per year etc. So far, only preliminary calculations for spiders and aculeate Hymenoptera have been performed.

Table 1. Numbers of species collected either in flight (window traps, sticky grids, yellow pans) or on the surface and in the vegetation layer (pitfall traps, sweepnet samples, suction samples). Only species with five or more individuals (left side in each column) were analysed with the help of transect distribution graphs.

Group	Total No. sp.		Flying		Crawling		Only in flight		Only Crawling	
	≥5ind.	<5ind.	≥5ind.	<5ind.	≥5ind.	<5ind.	≥5ind.	<5ind.	≥5ind.	<5ind.
Araneae	105	71	22	26	105	52	0	19	83	45
Carabidae	82	15	40	0	71	15	11	0	42	15
Staphylinidae	124	90	84	53	104	46	20	44	40	37
Heteroptera[1]	13	29	13	27	5	2	8	27	0	2
Syrphidae[2]	11	20	11	20	7	0	4	20	0	0
Coccinellidae	10	6	10	5	3	2	7	4	0	1
Neuroptera	8	15	8	15	2	0	6	15	0	0
Total Predators	599		334		414		185		265	
	353	246	188	146	297	117	56	129	165	100
% of total in class	59%	41%	56%	44%	71%	29%	34%	66%	63%	38%

[1]predatory; [2]aphidophagous

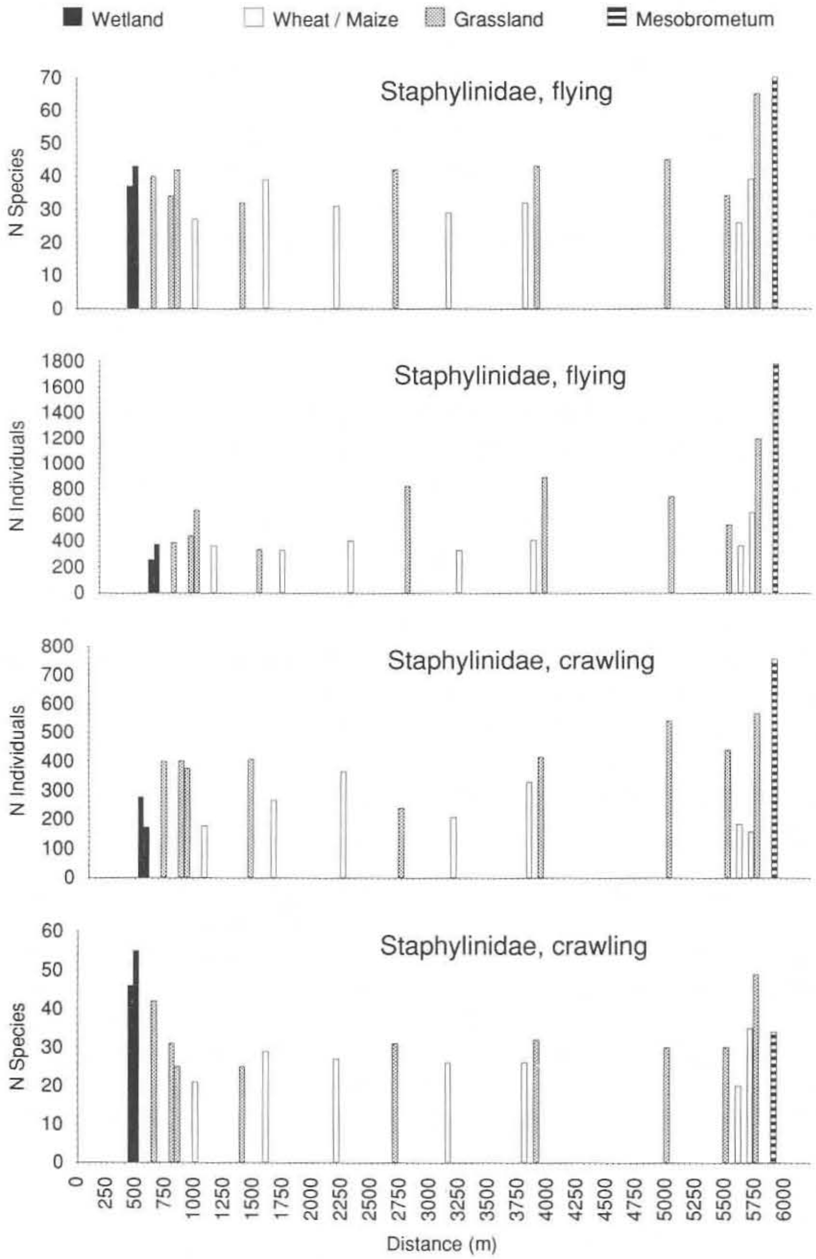

Fig. 2. Two-dimensional transect distribution graphs of staphylinid beetles. Habitat types are indicated with different filling patterns, including the wetland (left), the dry meadow (Mesobrometum, right), fertilized grassland and wheat, where the traps were moved into the nearest maize fields after wheat harvest in July.

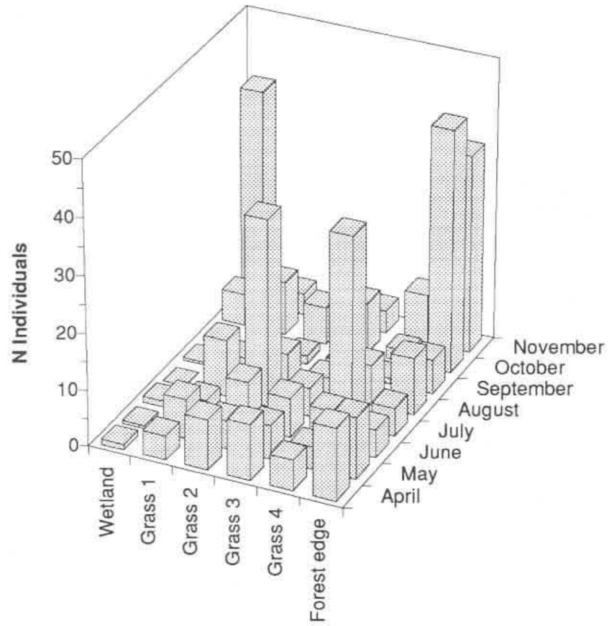

Fig. 3. Three-dimensional transect distribution graph of the common green lacewing, *Chrysoperla carnea* (Neuroptera), as an example of a nomadic species (dispersal type 5).

Dispersal types of predatory arthropods

In a third approach to the transect data, we address the following questions:

- What proportion of the predatory arthropod fauna (regarding either species or individuals) moves between natural habitats and cultivated areas, in other words: how many of them depend on natural or seminatural habitats outside the cultivated areas at certain times of their lives?
- What part of the predatory fauna develops within the cultivated fields and hibernates there or in the immediate surroundings in field margins?

On the one hand, we analysed the highly mobile groups of more or less specialized aphidophagous insects (Syrphidae, Coccinellidae, Neuroptera), on the other hand, we identified as many species as possible of the more polyphagous arthropods, where the spectrum ranges from flightless species to highly mobile fliers. The most important groups of polyphagous predators in cultivated areas are spiders, Carabidae, Staphylinidae and parts of the Heteroptera. The percentage of species collected in flight is highest in the Heteroptera and staphylinids, and lowest in the spiders.

We compared the number of species collected in flight traps like window

1. **Stenotopic species, spending their entire life cycle within one type of habitat.** (Identification: restricted to one habitat type, distribution type 1 in Fig.1)
2. **Species with a stronghold in or around natural or seminatural habitats, showing various degrees of diffusion into cultivated areas.** They are most likely not of agricultural importance, since they never reach high population levels in cultivated areas. They depend on natural or seminatural habitats for reproduction, development and hibernation. (Identification: maximum numbers in or close to natural areas, decreasing away from maxima; more than 33% in or around natural areas, distribution types 2 and 3 in Fig.1)
3. **Poor fliers or flightless species, hibernating at field margins or within fields.** Predators of high agricultural importance, independent of the presence of natural habitats. They require hibernation places in or close to cultivated areas. (Flight index below 10%, less than 33% of individuals in natural areas, distribution type 5 in Fig.1)
4. **Active fliers, present in all trap types at certain times of the year.** They hibernate in natural habitats outside of the cultivated areas, but have their main reproductive efforts in the fields. (Flight index above 10%, abundances in flight traps in spring and fall in most cases highest in or close to natural areas)
5. **Nomadic species, which depend on hibernation places outside the cultivated areas**, often quite far away, but mainly reproduce in the fields. The difference to dispersal type 4 is that their dispersal activity goes on during the reproductive period: they are true nomads and may change not only the fields regularly, but also may cover various regions. (Flight index above 50%, evenly spread over the entire transect. Abundances in spring and fall highest in or close to natural areas)
6. **Migrating species with no affinities to the habitat types in the transect area.** (Present only in flight traps, spread randomly over all habitat types)

Fig. 4. Dispersal types defined according to species parameters such as the percentage of specimens collected in flight traps, the percentage of specimens collected in or close to natural areas, and the transect distribution graphs.

traps, sticky grid traps and yellow water pan traps, with capture results from surface methods such as pitfall traps, sweepnet samples, and a suction device (Table 1). Of the total of almost 600 predatory arthropod species identified, 59% were collected in sufficient numbers to be displayed in a two-dimensional transect. Rare species were dominant in the Heteroptera, Syrphidae and Neuroptera (first column in Table 1). More than half of the 599 species were collected in flight (second column in Table 1), and even more (414) were caught crawling on the surface (third column in Table 1). 185 species were only collected in flight (fourth column) and 265 only in surface traps (fifth column).

For every taxonomic group, transect distributions for the number of species and the number of individuals per trap station were calculated. An example is given in Fig. 2 for the Staphylinidae. The species distribution of staphylinids collected in flight shows a maximum in the dry meadow along the forest edge

(top transect, right), which is even more evident in the distributions of numbers of flying and crawling individuals. Species numbers of staphylinids caught crawling, on the other hand, show their maximum in the wetland (bottom transect, left), which indicates that a large number of less frequent species are living in the wet area. The high numbers of species and individuals flying along the forest edge can be interpreted as migration flights to and from the hibernation places.

Further evidence for seasonal migration flights is given by three-dimensional transect distributions for species with more than a total of ten individuals collected. Many dispersive species show their maximum in the natural areas in early spring and/or autumn, while the maxima in the cultivated areas occur in late spring or summer. An example is given in Fig. 3, where the nomadic common green lacewing, *Chrysoperla carnea*, is active in the cultivated areas during the vegetation period, and after diapause induction in August accumulates in natural habitats for hibernation.

In addition to the distribution patterns in space and time for all species with more than ten individuals, a list with species specific information was created with the aim to form groups for distinct dispersal types for all the predatory spe-

Table 2. Example of a species list (staphylinid beetles) with the information leading to the assignment of a dispersal type (see Fig. 4) to every species.

Species List (Staphylinidae)	N	% in flight	Naturalness index	Distribution type 1-5	Dispersal type 1-6
Arpedium quadrum	2630	55.02%	36%	5	5
Anotylus tetracarinatus	2388	95.77%	11%	3	5
Carpelimus corticinus	2099	93.85%	61%	5	5
Paederus fuscipes	1509	28.56%	100%	3	4
Anotylus rugosus	1339	86.33%	65%	5	5
Philonthus carbonarius	946	57.51%	100%	4	5
Tachyporus hypnorum	912	29.50%	100%	5	4
Philonthus cognatus	905	25.41%	100%	5	4
Tachyporus nitidulus	603	40.30%	0%	5	4
Carpelimus gracilis	592	98.99%	48%	5	5
Platystethus arenarius	378	89.95%	100%	3	5
Xantholinus longiventris	378	8.73%	0%	3	2
Scopaeus laevigatus	364	81.59%	83%	3	4
Staphylinus caesarius	362	0.00%	71%	3	3
Tachyporus chrysomelinus	285	44.91%	100%	4	4
Lathrobium fulvipenne	262	4.96%	100%	4	2
Stenus biguttatus	226	4.87%	100%	5	2
Gabrius pennatus	220	59.09%	61%	4	5
Staphylinus dimidiaticornis	200	0.00%	79%	5	2
Carpelimus rivularis	192	100.00%	50%	2	3
Paederus litoralis	183	0.00%	100%	2	3
...	.	.	.	.	.
...	.	.	.	.	.

cies. The lists for the various taxonomic groups contain information on the total number of individuals collected per species, the percentage of individuals collected in flight, the percentage of individuals collected in natural or seminatural habitats, and the specific transect distribution type. With regard to all the available information, each species was assigned to one of six dispersal types (Fig. 4), and this information was also entered into the list, as shown in an example for the Staphylinidae in Table 2.

The six dispersal types shown in Fig. 4 were defined here for the purpose of grouping predatory arthropods according to their population movements between natural or seminatural habitats and cultivated areas. To avoid an interpretative bias from published observations in other parts of Europe, where certain species may show different habitat requirements, only informations emanating from the transect data were used for the grouping process.

The dispersal types 4, 5 and 6, if only looked at in the two-dimensional transect distribution, all look similar and would be regarded as "ubiquists" (distribution type 4 in Fig. 1).

Table 3. Contribution of the different taxonomic groups to the six dispersal types defined in Fig. 4 (only species with ≥5 indiv. classified). The species numbers in the classified total do not all correspond to the figures in Table 1, because some of the rare species could not be assigned to a specific dispersal type.

	Dispersal type							
	1	2	3	4	5	6	Sum	TOTAL
Araneae								
No. species	16	55	20	5	0	0	96	176
No. individuals	274	5202	44145	724			50345	50601
Carabidae								
No. species	9	30	24	5	10	2	80	97
No. individuals	376	5633	24343	6388	8949	84	45773	45830
Staphylinidae								
No. species	3	38	16	29	10	5	101	214
No. individuals	40	1865	1562	5272	10827	45	19611	20086
Heteroptera								
No. species	1	6	0	4	2	0	13	42
No. individuals	21	135		48	188		392	446
Coccinellidae								
No. species	3	2	0	0	5	0	10	16
No. individuals	254	718			2794		3766	3775
Syrphidae								
No. species	1	2	0	0	8	0	11	31
No. individuals	7	14			2157		2178	2218
Neuroptera								
No. species	1	3	0	0	3	1	8	23
No. individuals	6	30			671	7	714	743
All predators								
No. species	34	136	60	43	38	8	319	599
No. individuals	978	13597	70050	12432	25612	136	122805	123699

The various columns in the lists for each taxonomic group (example shown in Table 2) can be sorted according to different criteria. The species column can be sorted alphabetically or systematically. Sorting the second column for numbers of individuals allows us to group the dominant species and to visualize the correlation between abundance (number of catches, in fact) and flight activity, "naturalness", or dispersal type. Sorting the column dispersal type in turn allows an assessment of the correlation between a given dispersal type and the other parameters.

For each taxonomic group, the number of species and individuals per dispersal type was calculated (Table 3). Considering all predatory species, the dominant dispersal type is 2, i.e. species with a stronghold in or close to the natural habitats, but with dispersal capacities into the cultivated areas. The dominant dispersal type with regard to the number of individuals, however, is clearly type 3, with species staying predominantly in or close to cultivated areas.

Discussion

In the contribution presented here, the focus is on methodological aspects rather than on results and their interpretation.The 5 km long Limpach-transect of 1987 was, and still is, an extremely time consuming and therefore costly study, which involved numerous students, specialized taxonomists and computer experts. But the trade-off is obvious: there has hardly been any project in an agricultural landscape, where (1) several different habitat types have been investigated at the same time, with the same standardized methods, and for one full year, and (2) a wide spectrum of collecting methods has allowed a comparison within and between different groups of predators.

The methods are standardized in the sense that they were operated in the same manner in all transect stations. For a particular species the chance to get caught should be as similar as possible with regard to local abundance. We are aware of the fact that the same method may be of variable efficacy in different habitat types. This is particularly true for pitfall traps, and less so for the flight traps. The efficacy varies considerably for different species, but this does not affect the transect distribution at the species level. Another problem is, that in spite of the big efforts taken, not all predatory arthropod groups were adequately sampled (e.g. small spiders with nets close to the surface), or have not been identified so far (many Diptera and Coleoptera). Furthermore, only about half of the species were collected in sufficient numbers to interpret with some confidence their distribution in space and time. But in spite of these shortcomings, the large number of standardized collecting methods and the large number of taxa

considered will make this data set a useful empirical base for modelling spatial and temporal aspects of dispersal and metapopulation dynamics.

The proposed grouping of predatory species into dispersal types will help to quantify and functionally interpret population movements on a regional scale. To avoid oversimplification or even misinterpretation in the process of modelling, additional information from detailed studies on exemplary species have to be taken into consideration.

Of the six dispersal types defined in this paper, not all have the same importance for agriculture or nature protection, and not all have the same habitat requirements for reproduction, development and hibernation.

If we want to increase the biodiversity of predators, we should try to augment:

- type 1 and 2 dispersers by increasing natural habitats and creating a mosaic landscape,
- type 4 and 5 dispersers by increasing hedgerows, ecotone structures along forest edges and other arboreal habitats.

If we want to increase the overall abundance of predators (numbers of individuals, biomass, impact on pest insects etc.), we should try to augment:

- polyphagous type 3 disperser with grassy field margins, headlands and herbaceous strips along hedges,
- aphidophaga of type 4 and 5 with suitable hibernation sites in arboreal habitats and attract the nomadic species into fields with flowers or aphids on non-crop hosts.

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